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The degree and impact of differences in house price index measurement

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House price indexes (HPIs) while particularly important to the analysis of recessions, are prone to methodological and coverage differences which can undermine both within-country and cross-country economic analysis. The paper first uses a panel data set of 157 quarterly HPIs from 24 countries, along with associated measurement variables, to report on whether and how differences in HPI measurement matter. Second, revisits the modeling of the determinants of house price inflation using HPIs adjusted for differences in measurement practice.

Keywords: House price indexes, housing inflation, residential property price indexes

JEL Classification Numbers: C43, E30, E31, R31

1. Introduction

The October 2009 Report to the G-20 Finance Ministers and Central Bank Governors on the Financial Crisis and Information Gaps[2] described data on dwellings and their associated price changes as critical ingredients for financial stability policy analysis. Of the 46 systemic banking crises for which data are available, more than two-thirds were preceded by house price boom-bust patterns [5].[3] An understanding of deviations from equilibrium prices in housing markets requires reliable and, for international comparisons, consistently-measured, house price indexes (HPIs).[4]

[1]The views expressed herein are those of the author and should not be attributed to the IMF, its Executive Board, or its management.

[2]The initiative was taken up by the International Monetary Fund (IMF) Statistics Department (STA) and the Financial Stability Board (FSB). See: http://www.imf.org/external/np/seminars/eng/2010/infogaps/index.htm.

[3]Similarly, 35 out of 51 house price boom-bust episodes were followed by a crisis. The corresponding effect of stock market boom-busts was much smaller. Claessens et al. [4, p. 25] found that "recessions associated with house price busts are on average over a quarter longer than those without busts. Moreover, output declines (and corresponding cumulative losses) are typically much larger in recessions with busts, 2.2 (3.7) percent versus 1.5 (2.3) percent in those without busts. These sizeable differences also extend to the other macroeconomic variables, including consumption, investment and the unemployment rate." Reinhart and Rogoff [27] found the six major banking crises in advanced countries since the mid-1970s were all associated with a housing bust.

[4]The term "HPIs" includes apartments and is interchangeable with residential property price indexes.

Yet HPIs are particularly prone to methodological differences, which can undermine both within-country and cross-country analysis. It is a difficult but important area. There are empirical questions as to first, whether measurement differences matter and, if so, how and to what extent, and second, how such differences impact on the analytical work of modeling HPI changes. A brief outline of measurement problems and practices is given in Section 2 which also notes a number of initiatives to harmonize HPI methodology.

The empirical analysis in Section 3 is based on a panel data set of five years of quarterly series for over 150 HPIs from nearly 25 countries; all the series differ (at least within countries) with regard to their methodological features. A fixed effects (for country) model with HPI changes regressed on measurement characteristics can identify the extent to which measurement differences matter and the salient measurement features.

Given the importance of measurement in explaining HPI variation, as established in Section 3, we determine the effect measurement has on the economic analysis of house price inflation. In Section 4, national measurement-adjusted and unadjusted HPIs are compared in an illustrative economic model of the determinants of house price inflation.

2. The potential for mismeasurement and international guidelines

For any individual dwelling a house price transaction is infrequent. Further, individual dwellings are highly heterogeneous. Comparing the prices of like with like on a regular basis is highly problematic.

First, there are no transaction prices every period, say quarter, on the same property. HPIs have to be compiled from infrequent transactions on heterogeneous properties. Price index measurement for consumer, producer and export and import price indexes (CPI, PPI and XMPIs) largely rely on the *matched-models method.* The detailed specification of one or more representative brand is selected as a high-volume seller in an outlet, and its price recorded. The outlet is then revisited in subsequent months, the price of the self-same item recorded and geometric averages of its price and those of similar such specifications in other outlets form the building blocks of a CPI. Of course, individual items may be infrequently traded. An individual tomato, for example, is not sold more than once as a final retail transaction. However, the similarities between tomatoes (of a particular species, quality, sold in a particular outlet) are relatively great; tomatoes are close substitutes. Each month the prices can be collected on the self-same quality of tomato. The heterogeneity of dwellings precludes this because similar houses, in terms of their price-determining characteristics, including location, are not sold each quarter. Quarterly individual house prices observed and measured are few and far between and the houses transacted each quarter can be very dissimilar with respect to many price-determining characteristics including lot and structure size, number of bathrooms, bedrooms, condition,

age, location and much more. The average prices in one period cannot be compared with those in subsequent ones as a measure of pure price change. A higher (lower) proportion of more expensive houses sold in one quarter should not manifest itself as a measured price increase (decrease). There is a need in measurement to control for changes in the quality of houses sold, a non-trivial task.

The main methods of quality adjustment are hedonic regressions, use of repeat sales data only, and mix-adjustment by weighting detailed homogeneous strata, and the sales price appraisal ratio (SPAR).[5] The method selected depends on the database used. There needs to be details of salient price-determining characteristics for hedonic regressions, a relatively large sample of transactions for repeat sales, and good quality appraisal information for SPAR. In the US, for example, price comparisons of repeat sales are mainly used, akin to the like-with-like comparisons of the matched models method, Shiller [28]. There may be bias from not taking full account of depreciation and refurbishment between sales and selectivity bias in only using repeat sales and excluding new home purchases. However, the use of repeat sales does not requires data on quality characteristics and controls for some immeasurable characteristics that are difficult to effectively include in hedonic regressions, such as a desirable or otherwise view.

Second, the data sources are generally secondary sources that are not tailor-made by the national statistical offices (NSIs), but collected by third parties, including the land registry/notaries, lenders, realtors (estate agents), and builders. An exception is the use of buyer's surveys in Japan. The adequacy of these sources to a large extent depends on a country's institutional and financial arrangements for purchasing a house and vary between countries in terms of timeliness, coverage (type, vintage, and geographical), price (asking, completion, transaction), method of quality-mix adjustment (repeat sales, hedonic regression, SPAR, square meter) and reliability; pros and cons will vary within and between countries. In the short-medium run users are dependent on series that have grown up to publicize institutions, such as lenders and realtors, as well as to inform.

Key HPI measurement variables include the: (i) use of stocks or flows (transactions) for weights; (ii) use of values or quantities for weights; (iii) use of fixed or chained weights; (iv) the method of enabling constant quality measures (repeat sales pricing, hedonic approach, mix-adjustment through stratification, sale price appraisal ratio (SPAR)); (v) geographical coverage (capital city, urban etc.); (vi) coverage by type of housing (single family house, apartment etc.); (vi) vintage covered, new or existing property; and (vii) valuation method (and source data) of prices (asking, transaction, appraisal etc.).

[5]Details of all these methods are given in the Eurostat et al. [11]; see Hill [16] for a survey of hedonic methods for residential property price indexes; Silver and Heravi [33] and Diewert et al. [8] on hedonic methods; Diewert and Shimizu [7] and Shimizu et al. [34] for an application to Tokyo; and on repeat-sales methodology, Shiller [28–30].

For many countries more than one national index is available each using quite different methods and having different coverage. Silver [32] illustrates the substantial *within* country variation of national HPIs by different compiling organizations for three case studies, Russia, the United Kingdom, and the United States – see also Careless [3].

Positive developments includes (i) the publication of international standards on HPI methodology: the Eurostat et al. [11] *Handbook on Residential Property Price Indices*;[6] (ii) an impressive array of data hubs dedicated to the dissemination of house price indices and related series including the IMF's Global Housing Watch; the Bank for International Settlements' (BIS) Residential Property Price Statistics; the OECD Data Portal; the Federal Reserve Bank of Dallas' International House Price Database; Eurostat Experimental House Price Indices; and private sources;[7] and (iii) encouragement in compiling and disseminating such measures: real estate price indexes are included as Recommendation 19 of the G-20 Data Gaps Initiative (DGI), and residential property price indexes prescribed within the list of IMF Financial Soundness Indicators (FSIs), in turn included in the IMF's new tier of data standards, the Special Data Dissemination Standard (SDDS) Plus.[8] Experimental results have been developed by Eurostat [10] on the development of comparable HPIs for owner-occupied housing (OOH) in the framework of the Harmonized Indexes of Consumer Prices (HICP) for countries in the euro area and at the European Union level,[9] see also Eurostat [9].

The application of international guidelines on measurement is not straightforward given the dependency of HPIs on secondary source data. Further, HPIs are often published by private organizations such as realtors and lenders and also serve to advertise their business. Private organizations are unlikely to abandon their indexes if their source data and methods do not meet newly developed international guidelines.

[6] http://epp.eurostat.ec.europa.eu/portal/page/portal/hicp/methodology/hps/rppi_handbook.

[7] The IMF's Global Housing Watch provides current data on house prices for 52 countries as well as metrics used to assess valuation in housing markets, such as house price-to-rent and house-price-to-income ratios: http://www.imf.org/external/research/housing/; the BIS has extensive country series on HPIs along with details of, and links to, country metadata and source data: http://www.bis.org/statistics/pp.htm; OECD also disseminates country house price statistics and is developing a wide range of complementary housing statistics: http://www.oecd.org/statistics/; the Federal Reserve Bank of Dallas' International House Price Database, Mack and Martínez-García [24], at: http://www.dallasfed.org/institute/houseprice/index.cfm; and Eurostat Experimental House Price Indices at: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=prc_hpi_q&lang=en.

[8] The setting of such standards is a key element of Recommendation 19 of the report: *The Financial Crisis and Information Gaps,* endorsed at the meeting of the G-20 Finance Ministers and Central Bank Governors on November 7, 2009; see Heath [14] for details of SDDS Plus and the DGI and http://fsi.imf.org/ for FSIs under "concepts and definitions."

[9] Eurostat has published, since February 2012, a Macroeconomic Imbalance Procedure (MIP) Scoreboard for the surveillance of macroeconomic imbalances. The scoreboard consists of a set of ten indicators that include house price indices (HPIs) taken from the experimental HPI for which data are publicly available in the Eurostat HPI release. Missing experimental HPIs have also been included in the Scoreboard based on other non-harmonised sources. Further information from: http://epp.eurostat.ec.europa.eu/portal/page/portal/hicp/methodology/owner_occupied_housing_hpi/experimental_house_price_indices.

3. Does measurement matter? International evidence

There is evidence of differential HPI growth rates between countries.[10] But there is also a variety of quite dispirit methods employed between countries for calculating HPIs. In this section we employ a panel regression that attempts to distinguish measurement effects from house price inflation. The software used was EVIEWS Version 7.2 (Quantitative Micro Software, Standard Edition, 2013) on a 64-bit Windows 7 Enterprise Operating System.

3.1. The HPI series

The study is based on a panel of about 157 quarterly HPIs from 24 countries over 2005:Q1 to 2010:Q1. Details of the HPI series are given in Appendix 1. Log rates of changes in quarterly HPIs are defined below for HPI series $i = 1, \ldots, N_c$ in country $c = 1,\ldots, C$ over $t = 1,\ldots, T$ quarters where N_c is the number of HPIs in country c, published in each country and included in this study, and $N = \sum_{c=1}^{C} N_{c.}$.

$$dhpi_{i,c}^{t} = \ln\left(\frac{hpi_{i,c}^{t}}{hpi_{i,c}^{t-1}}\right) \tag{1}$$

Our concern is explaining variation in HPI *rates*, not levels. For 2005:Q1 to 2010:Q1 the bias-adjusted Levin, Lin, and Chu [23] $t*$ statistic of -30.2116 rejected the null hypothesis that each individual series had a common integrated time series versus the alternative hypothesis that all individuals series are stationary (p-value $= 0.0000$).[11]

3.2. Coverage and measurement of explanatory variables

Explanatory measurement variables are classified into those based on data coverage (vintage, geographical classification, type of dwelling) and those based on methodology. These measurement variables include:

[10] Hilbers et al. [15] demonstrated the variability in European country HPI growth rates by distinguishing between European countries according to their HPI average (real) growth rate between 1985 and 2005–07. House prices in Spain, Belgium, Ireland, the United Kingdom, the Netherlands, and France more than doubled; the Nordic countries, Italy and Greece increased by about 50–100 percent; and Germany, Austria, Switzerland, and Portugal remained largely flat or fell over the two decades.

[11] The bias adjusted $t*$ given by Eq. (12) in Levin et al. [23] has an asymptotically normal distribution. The adjustment is necessary because the unadjusted t does not converge to a standard normal distribution under models with individual-specific intercepts and both individual-specific intercepts and trends (models 2 and 3 respectively in Levin et al. [23, p. 4]); see also . *EViews 7 Users Guide II* (Quantitative Micro Software: Irvine CA), page 397.The null hypothesis of unit roots for this pooled data set was also rejected when tested using the Im, Pesaran and Shin W-statistic of 46.135 (p-value $= 0.0000$), the ADF Fisher Chi-square statistic of 2,505.39, (p-value $= 0.0000$), and the Phillips and Perron Fisher Chi-square statistic of 3,525.37 (p-value $= 0.0000$).

Based on coverage

- ***Vintage*** (benchmarked on ***both*** new and existing dwellings). **New** (newly constructed dwelling)= 1 (0 otherwise); **Xsting** (existing dwelling) = 1(0 otherwise).
- ***Geographical coverage*** (benchmarked on ***national*** coverage). **Capital** (major) city = 1 (0 otherwise); **Big cities** = 1 (0 otherwise); **Urban** areas = 1 (0 otherwise); **notcapital** = 1 (0 otherwise); **Rural** = 1 (0 otherwise).
- ***Type of dwelling*** (benchmarked on ***both*** apartments and single-family homes). **Apartment** = **1** (0 otherwise); Single family home (**Sfh**) = 1 (0 otherwise).

Based on method

- ***Quality-mix adjustment*** (benchmarked on ***price per dwelling,*** no adjustment). **Hedonic** regression-based = 1 (0 otherwise); **Repeat** sales = 1 (0 otherwise); **SPAR** = 1 (0 otherwise); **MixAdjust** = 1 (0 otherwise); **SqMeter** = 1 (0 otherwise).
- ***Type of price*** (benchmarked on ***transaction price***). **Asking** price = 1 (0 otherwise); Tax/mortgage **Appraisal** price = 1 (0 otherwise).
- ***Weights: as a flow of sales transactions or stock*** (benchmarked on ***sales*** = 0)**.** **Wstock** = **1** (0 otherwise).
- ***Weights: quantity or value or other shares*** (benchmarked on ***value*** = 0). **Wquantity** = 1 (0 otherwise); **Wsqmeter** = 1 (0 otherwise); **Wpop**ulation = 1(0 otherwise); **Wprice** in base-period = 1 (0 otherwise).
- ***Weights: fixed or chained/regularly-updated or unweighted*** (benchmarked on ***fixed*** = 0). **Wchain** = **1** (0 otherwise); **Unweighted** = 1 (0 otherwise).
- ***Weights: rolling/average or annual*** (benchmarked on ***annual*** = 0). **Wrolling** = **1** (0 otherwise).
- **Aggregation at higher level**: geometric or arithmetic (benchmarked on arithmetic). **Geometric** = **1** (0 otherwise).

Interaction variables were included, but with little success.

The categorization of measurement variables was not always straight forward. For example, for the Austrian HPIs, the *Immobilienpreisindex*, one third of the data are transaction prices and two thirds are quotation prices; the index was characterized as being based on the latter. Nonetheless, as will be seen in subsequent sections, the catagorizations used successfully explained much of house price inflation.

Methodological information on source data and compilation methodology including coverage, method of quality adjustment, weighting and aggregation procedures was taken from the methodological notes attached to the source data, survey papers and, often, extensive email correspondence with the providing institutions. The provision of information was on condition that confidentiality would be respected.

3.3. The results

The regression relates inflation for series $i = 1,\ldots,I$, in periods $t = 1,\ldots, T$ on each of the time-varying $k = 1, K$ coverage (*COV*) and $l = 1,\ldots, L$ methodological

(*METH*) explanatory variables outlined in section B above; fixed time, D_i^t, effects that takes a value of 1 if the series is for period t, and 0 otherwise; and fixed country, $D_{i,c}$, effects that takes a value of 1 if the series is for country $c = 1,\ldots, C$, and 0 otherwise. The regression model is:

$$dhpi_i^t = \sum_{k=1}^{K} \gamma_k^t COV_{i,k}^t + \sum_{l=1}^{L} \delta_l^t \, \mathbf{METH}_{i,l}^t + \sum_{t=1}^{T} \beta^t D_i^t + \sum_{c=1}^{C} \lambda_c D_i^t + \varepsilon_i^t \quad (2)$$

The estimator is a cross-section SUR specification to allow for conditional correlation between the contemporaneous residuals for cross-sections (but restricts residuals in different periods to be uncorrelated), and to allow for cross-sectional heteroskedasticity (Beck and Katz [2]. SUR cross-sectional estimators are widely used, for example Nieh and Ho [26] and Arouri et al. [1]).

As noted, the model in Eq. (2) has time-varying parameters on the coverage and methodological variables to identify whether and how their importance, as explanatory variables, might changes over time. A priori, we should expect coverage and measurement effects to vary over time. Specifically, outside of a recession the irrational exuberance of house price inflation [31] may be relatively evenly spread across most geographical regions of an economy, types of housing, quality-mix, stage at which priced, and so forth. Differences in coverage and measurement may not matter so much. But with major turning points the increasing unexpected component of house price inflation might be argued to lead to increased dispersion in house price inflation – an argument mirroring Friedman [12] – giving a greater importance to proper measurement. The explanatory power of coverage and measurement variables should increase with and during a recession. It is an empirical matter, arguing against a restriction of the coefficients to not vary with time. We tested and rejected null hypotheses of restrictive fixed parameter over time, i.e. $\gamma_k = \gamma_k^t$ and $\delta_k = \delta_k^t$ in Eq. (2);[12] models with time-varying parameters, interaction terms between each such variable and time, were found to be superior.[13] The specification in Eq. (2) with time-varying parameters also includes fixed-time effects and fixed country effects. The methodological explanatory variables were categorized, as noted in section IIIB above, as those based on coverage and method. The results for moving window regressions are given in Table 1.

[12]Likelihood-ratio tests were used to test the null hypotheses of inclusion in the model as time-varying coefficients against fixed (over time) coefficients for each explanatory variable. Time-varying coefficients were included for *apartment*, *appraisal*, *asking*, *capital*, *hedonic*, *mixadjust*, *new*, *sfh*, *unweighted*, *wprice*, *wrolling* and *wstock*. The null hypothesis of redundant time-varying coefficients variables in the unrestricted model was rejected for each of the above variables at the 5 percent level and for *asking*, *capital* and *sqmeter* at the 10 percent (p-values = 0.067, 0.0636, and 0.0667 respectively). The selection was based on the results from a general model for the whole period rather than optimal parsimonious representations for the sub-periods of moving window regressions.

[13]Of note is the low $\bar{R}^2$ of 0.0503 when fixed (over time) measurement variables and fixed effects are included. Results provided in Appendix 2 Table 4.

Table 1
Fit of measurement variables in moving window regression

	RbarSq including: Time; Country; Measurement	Country Measurement	Measurement	Measurement	
				Coverage	Methodology
05 Q1	0.322	0.211	0.102	0.015	0.079
05 Q2	0.253	0.242	0.120	0.016	0.099
05 Q3	0.282	0.273	0.126	0.023	0.099
05 Q4	0.330	0.324	0.148	0.083	0.114
06 Q1	0.365	0.358	0.120	0.025	0.100
06 Q2	0.416	0.409	0.103	0.004	0.090
06 Q3	0.347	0.343	0.085	0.003	0.081
06 Q4	0.286	0.282	0.070	0.003	0.069
07 Q1	0.266	0.265	0.077	0.009	0.075
07 Q2	0.182	0.177	0.100	0.051	0.095
07 Q3	0.181	0.175	0.110	0.066	0.093
07 Q4	0.193	0.193	0.110	0.074	0.081
08 Q1	0.264	0.254	0.153	0.101	0.116
08 Q2	0.303	0.281	0.195	0.129	0.146
08 Q3	0.343	0.324	0.234	0.128	0.194
08 Q4	0.358	0.342	0.216	0.114	0.164
09 Q1	0.405	0.369	0.228	0.118	0.174
09 Q2	0.445	0.408	0.267	0.158	0.211
09 Q3	0.456	0.444	0.257	0.137	0.194
09 Q4	0.401	0.397	0.175	0.068	0.087
10 Q1*	0.413	0.415	0.099	0.020	0.051

Numbers are for 5-quarters' moving (by one quarter) window regressions appropriately centered. Figures for 2009:Q4 and for 2010:Q1 are based on regressions over 2009Q2-2010:Q1 and 2009Q4-2010:Q1 respectively. *The RbarSq are very similar for 2010Q1 for the first two columns, with and without the time dummies. The degrees of freedom adjustment is responsible for the latter exceeding the former.

First, the regressions have substantial explanatory power, $\bar{R}^2$ at about 0.45 in mid-2009, a result especially notable given only fixed effects, and measurement variables were included. There were no structural explanatory variables to explain house price inflation by means of supply and demand (and financing) of a country's housing market as in, for example, Muellbauer and Murphy [25].[14] It can be seen from the results of Table 1, column 2, that measurement matters and, in particular, that $\bar{R}^2$ increases over the period of recession, when it really matters.

Second, Table 1 shows the explanatory power of the model is not substantively driven by the fixed time and country effects. On excluding the country- and time-fixed effects (Table 1, column 4) the effect of the measurement variables alone, while diminished, accounted during the recession for about a quarter of the variation in house price inflation rates.

Third, is the question: given that measurement matters, what matters most, coverage variables or methodological variables? Table 1, columns 5 and 6 find that drop-

[14]The paper finds the main drivers of house prices to include income, the housing stock, demography, credit availability, interest rates, and lagged appreciation.

Table 2
Illustrative regression results for 2009:Q1 to 2009Q2

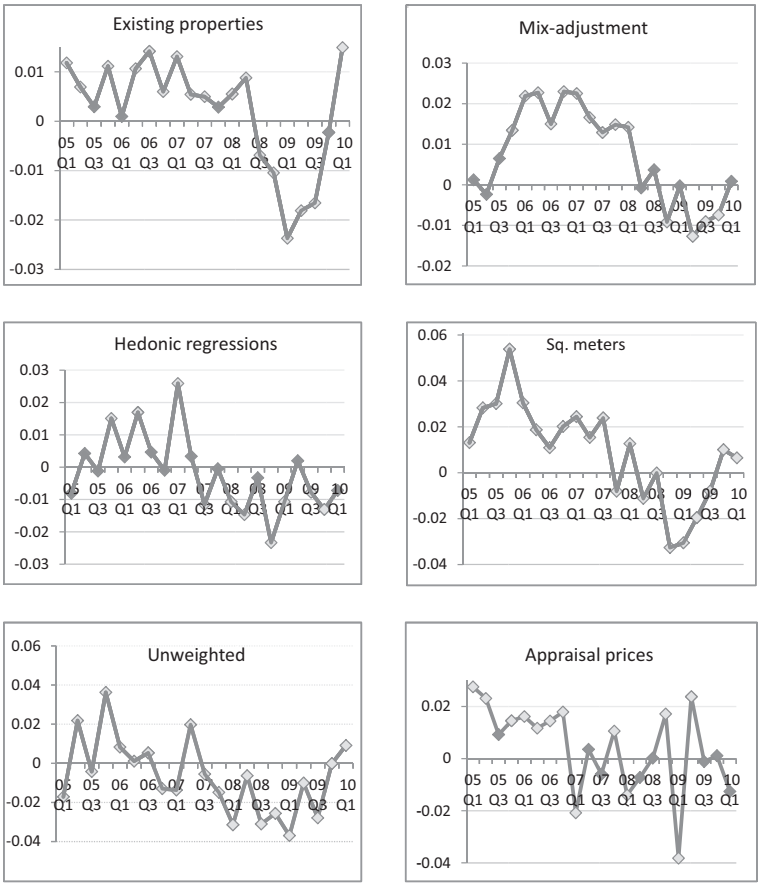
Variable	Coefficient	Std. Error	t-statistic	p-value
C	0.006	0.004	1.377	0.17
WSTOCK	−0.006	0.010	−0.589	0.56
APARTMENT–2009Q1	−0.004	0.002	−1.982	0.05
APARTMENT–2009Q2	−0.014	0.002	−5.562	0.00
APPRAISAL–2009Q1	−0.032	0.006	−4.871	0.00
APPRAISAL–2009Q2	0.034	0.008	4.502	0.00
ASKING–2009Q1	0.025	0.003	9.601	0.00
ASKING–2009Q2	0.020	0.002	8.121	0.00
CAPITAL–2009Q1	−0.014	0.003	−4.902	0.00
CAPITAL–2009Q2	0.001	0.002	0.565	0.57
HEDONIC–2009Q1	0.005	0.005	1.011	0.31
HEDONIC–2009Q2	0.016	0.004	3.695	0.00
MIXADJUST–2009Q1	0.019	0.007	2.690	0.01
MIXADJUST–2009Q2	0.004	0.007	0.524	0.60
NEW–2009Q1	0.002	0.006	0.346	0.73
NEW–2009Q2	−0.024	0.005	−5.036	0.00
SFH–2009Q1	−0.011	0.002	−6.751	0.00
SFH–2009Q2	−0.003	0.002	−1.944	0.05
SQMETER–2009Q1	−0.013	0.013	−0.975	0.33
SQMETER–2009Q2	−0.013	0.013	−1.001	0.32
UNWEIGHTED–2009Q1	−0.006	0.006	−1.026	0.31
UNWEIGHTED–2009Q2	0.014	0.006	2.462	0.01
WPRICE–2009Q1	0.022	0.012	1.771	0.08
WPRICE–2009Q2	−0.012	0.012	−1.031	0.30
WROLLING–2009Q1	−0.009	0.002	−4.331	0.00
WROLLING–2009Q2	−0.011	0.003	−4.414	0.00
XSTING–2009Q1	0.000	0.004	−0.057	0.95
XSTING–2009Q2	−0.001	0.004	−0.194	0.85
2009Q2–C	0.008			
R-squared	0.592	Adjusted R-squared	0.506	
S.E. of regression	0.033	Log likelihood	619.6	

Sample: 2009Q1 2009Q2; 148 cross-sections; 295 obs. Fixed country effects not shown for brevity.

ping either set leaves the other with substantial explanatory power, though "method" is for the large part slightly more important than "coverage."[15]

Table 2 provides results for an illustrative regression which allow coefficients of measurement variables to change over time, for brevity, over the two quarters 2009Q1 to 2009:Q2. $\bar{R}^2 = 0.592$ with 15 of the 26 (13 in two periods) variables statistically significant at the 5 percent level. The impact of the variables is quite

[15]There is likely to be some intercorrelations between the variable sets For example, in the United States, the repeat purchase method is used to hold constant the quality mix of transactions for existing houses, but for new houses sold only once, the hedonic method is used, since new houses (coverage) will generally have only one transaction (method). More generally, Land Registry data based on transaction prices often has a large coverage, but limited characteristic variables, arguing against the use of hedonic regressions, while the opposite applies to realtor data based on asking prices.



Figs. 1–6. Varying estimated parameters.

volatile over time; a variable being significant in one quarter is no guarantee of it being so in the next.

Figures 1–6 illustrate the nature, magnitude and volatility of individual regression coefficients over time for six illustrative explanatory variables: the coverage of existing properties (as against new and existing); use of stratified mix-adjustment (as against price per dwelling); hedonic regressions (as against price per dwelling); price per sq. meter (as against per dwelling); unweighted or equal weights (as against value shares), appraisal (as against transaction) price data.

A lighter-fill marker in the Figures indicates that the coefficient's value is statistically significant at a 5 percent level. In general, the coefficients of these measurement variables are lower, yet statistically significant, during the recession compared with prior to it. There is, in some cases, a marked volatility to these coefficients, as illustrated in Fig. 6 for the use of appraisal prices as against transaction prices.

Having shown that measurement issues matter when comparing HPIs, and that they matter particularly during the recession – when it matters – we turn to a consideration of the impact of these findings on some macroeconomic analytical work.

4. Modelling house price changes using cross-country/pooled data

Much analysis of the impact of house price inflation on the recession uses cross-country comparisons or regional aggregates. The concern here is with the sensitivity of such analysis to measurement issues.

There is naturally much concern in the literature with the relationship between (real) house price booms and banking busts including Igan and Loungani [17], Crowe et al. [6]; Claessens et al. [5] IMF (2008, 2010, and 2011), and Reinhart and Rogoff [27]. Empirical work is often based on a sample of countries[16] and includes analysis of the cross-country coincidence of real house price index changes, the magnitude, duration, and characteristics of house price cycles, and cross-country relationship between HPI changes and those of other macroeconomic and household financial variables. Implicit in such analysis is the assumption that changes in HPIs due to measurement-related differences are not of a nature/sufficient magnitude to adversely affect the results. We have demonstrated in Section IIIC that measurement differences do have a major effect on changes in the house price index, especially so at turning points.

We take the econometric model in Igan and Loungani [17] (hereafter IL) to illustrate the impact of measurement differences on such analytical work. We stress our and their estimates are not directly comparable. Their estimates are from a regression using (unbalanced) pooled quarterly HPIs from 17 countries over 1970Q1 to 2010Q1. This contrasts with our a shorter period of 2005:Q1 to 2010Q1 and use of a panel data set of about 150 HPI series over a similar, but extended, set of 21 countries. Country house price inflation for our work is estimated using time-varying country effects in a regression of house price inflation for these about 150 series that also includes measurement variables. The regression allows the estimate of each country's inflation to vary over time, via separate country-time interaction dummy variables, $\lambda_c = \lambda_c^t$ in Eq. (2).[17] The resulting estimates of λ_c^t were, for the large part (about 75 percent of the 441 estimates – 21 countries by 21 quarterly changes), statistically significant at a 5 percent level. We employ the same estimator (OLS with

[16] Work has also been undertaken for states within countries, for example Igan and Kang [18] for within Korea and the United States.

[17] We follow Kennedy [22] and use as the estimate of the proportional impact of the period t time dummy for country c, in this semi-logarithmic regression, the consistent (and almost unbiased) approximation: $\left[\exp\left(\hat{\lambda}_c^t\right) \Big/ \exp(V(\hat{\lambda}_c^t)/2)\right]$-1 where $\hat{\lambda}_c^t$is the OLS estimator of $\lambda_c^t = \lambda_c$ in Eq. (2) above and $V(\hat{\lambda}_c^t)$ is its estimated variance. The approximation is shown by Van Garderen and Shah [35] and Giles [13] to be extremely accurate, even for quite small samples.

Table 3
Pooled regression results for house price indexes

Dependent variable	House price index, log quarter-on-quarter change: Excluding: Affordability-lag squared				
	Igan and Loungani (2012) (1)	Measurement-adjusted estimates (2)	Unadjusted estimates (3)	Measurement-adjusted estimates (4)	Unadjusted estimates (5)
Affordability, lagged	−0.0269***	−0.291*	−0.174	−0.085**	−0.077***
	(0.0041)	(0.1772)	(0.1201)	(0.037)	(0.0271)
Income per capita, change	0.429***	0.392**	0.519***	0.395***	0.520***
	(0.0684)	(0.1516)	(0.0917)	(0.142)	(0.0919)
Working-age pop, change	0.991***	0.735*	0.494**	0.754*	0.503**
	(0.1980)	(0.3941)	(0.2354)	(0.411)	(0.2438)
Stock prices, change	0.0048*	−0.017**	−0.007	−0.016*	−0.00604
	(0.0027)	(0.0086)	(0.0071)	(0.010)	(0.0077)
Credit, change	0.0187***	0.165***	0.191***	0.156***	0.186***
	(0.0052)	(0.0268)	(0.0253)	(0.031)	(0.0273)
Short-term interest rate	−0.0009**	−0.010**	−0.006**	−0.010**	−0.006**
	(0.0004)	(0.0046)	(0.0025)	(0.005)	(0.0025)
Long-term interest rate	−0.0006	0.000001***	0.000	0.000006***	0.000002
	(0.0004)	(0.0000)	(0.0000)	(0.0000)	(0.0000)
Affordability, lag, squared		−0.014	−0.007		
		(0.0121)	(0.0085)		
Construction costs, change	0.127***	0.320*	0.312*	0.285*	0.295*
	(0.0365)	(0.1671)	(0.1709)	(0.172)	(0.1738)
Constant	−0.243***	−1.267**	−0.838**	−0.553**	−0.504***
	(0.0554)	(0.6384)	(0.4232)	(0.247)	(0.1796)
No. Obs.	1,297	357	357	357	357
No. of periods	1970Q1-2010Q1	2005Q1-2010Q1	2005Q1-2010Q1	2005Q1-2010Q1	2005Q1-2010Q1
No. countries	17	17	17	17	17
Redundant country effect:		48.94	60.72	46.6	59.10
		(0.0000)	(0.0000)	(0.0001)	(0.0000)
R-squared	0.18	0.29	0.54	0.29	0.54

The dependent variable is the log change in the house price index over the last quarter. Affordability is defined as the log of the ratio of house prices to income per capita. Log change in income per capita is calculated as the quarter-on-quarter change in the log level. Log changes in working-age population and bank credit to the private sector are calculated as the year-on-year change in log levels. Log change in stock prices is calculated as the lagged year-on-year change in the log level. All variables are in real terms except short-term and long-term interest rates. Robust standard errors are in parentheses. ***, **, *denote significance at the 1, 5, and 10 percent level, respectively. The sample was restricted to 17 countries to enhance comparability with Igan and Loungani; the results were substantively the same irrespective of the restriction.

robust standard errors), variable list, and dynamics used by IL. Our comparators are between their model but estimates with our measurement adjusted and unadjusted HPIs.

Table 3, column 1 are the results by IL from their pooled regression – further details and rationale for their model are given in pages 14–17 of their paper. Quite similar results are found from our analysis given in columns 2 and 3 of Table 3 with the expected signs on the estimated coefficients. Given the quite major differences in

the data sets used here and by IL, this study gives further credence to their work. Affordability is not statistically significant at a 5 percent level, but becomes so (columns 4 and 5) when its square is dropped.[18]

The measurement-adjusted (Madj) estimates in columns 2 and 4 improve on the respective unadjusted ones in columns 3 and 5. Table 3 shows both stock price changes and long-term interest rates have no (statistically significant at a 5 percent level) affect on HPI changes both for the IL estimates (column 1)[19] and unadjusted estimates (columns 3 and 5), but do so with the appropriate sign for the measurement-adjusted estimates (columns 2 and 4).[20] For some cases, parameter estimates for Madj price changes have larger falls and smaller increases than their unadjusted counterparts. For example, Madj and unadjusted house price inflation are estimated to *fall* by 8.5 and 7.7 percent respectively as (lagged) affordability increases by 1 percent, to *increase* by 0.40 and 0.52 percent respectively as the change in income per capita increases by 1 percent, and to *increase* by 0.156 and 0.186 percent respectively as the change in credit increases by 1 percent.

Evaluating the Madj and unadjusted models in terms of relative explanatory power is not straightforward. While the R-squared for the different regressions differ, this is not a valid basis for comparison since each regression explains variation in a different variable set. An alternative measure is the Chi-squared statistic for a redundant country fixed-effects test. Such effects should be smaller for the measurement-adjusted regression than the unadjusted one, if the measurement variables are doing their work. This can be seen to be the case from Table 3; the Chi-squared statistics for the Madj regression model are 48.9 and 46.6 (columns 2 and 4) compared with 60.7 and 59.1 (columns 3 and 5) for the respective unadjusted estimates. Thus while the regressions remain relatively robust to measurement issues, individual parameter estimates do benefit from adjustments for measurement differences.

One issue of interest to this study, and also cited and explored by IL, is the cross-country variability in the parameter estimates. In Fig. 7 we show the result of relaxing the restriction on the 8 estimated parameters to be constant across the 17 countries, for both measurement-adjusted and unadjusted HPIs. The individual results are for the large part – over 70 percent of the 272 estimates – statistically significant at a 5 percent level. Of note is that while stock price changes and long-term interest rates

[18]Excluded from Table 3 are the country effects (available for the authors) required by our model given that more than one series is used for each country. F-tests on the redundancy of these country effects found the null hypothesis of no such effects to be rejected at a 1 percent level ($F = 3.735$ and 2.887 respectively for the measurement-adjusted and unadjusted estimates).

[19]If in IL "construction costs" is dropped, "stock prices" becomes statistically significant, IL (2012, Table 5).

[20] The coefficient for stock prices in column (4) denoted as statistically significant at a 10 percent level was in fact a borderline p-value of 0.1056. We used a (White) period heteroskedasticity adjustment to the standard errors. Had a diagonal or cross-sectional one been applied the p-values would have been 0.017 and 0.069 respectively, compared with p-values of 0.2076 and 0.1884 for the unadjusted estimates.

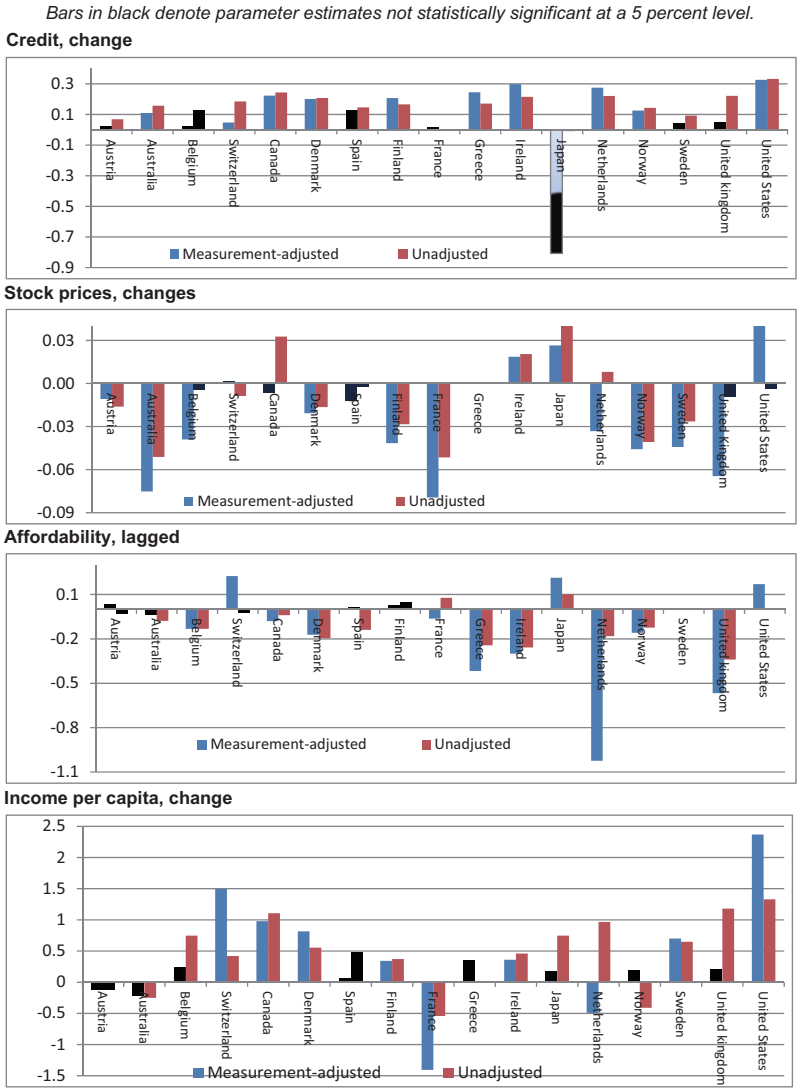


Fig. 7a. Country variability in parameter estimates. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/JEM-150406)

were not statistically significant when related to the unadjusted measure of housing inflation in the restricted model, Table 3, these country-specific estimates were found to be generally statistically significant when allowed to vary across countries, Fig. 7. The nature and extent of the country effect differed across series. In some cases, stock prices, affordability, and long-term interest rates, there is evidence of

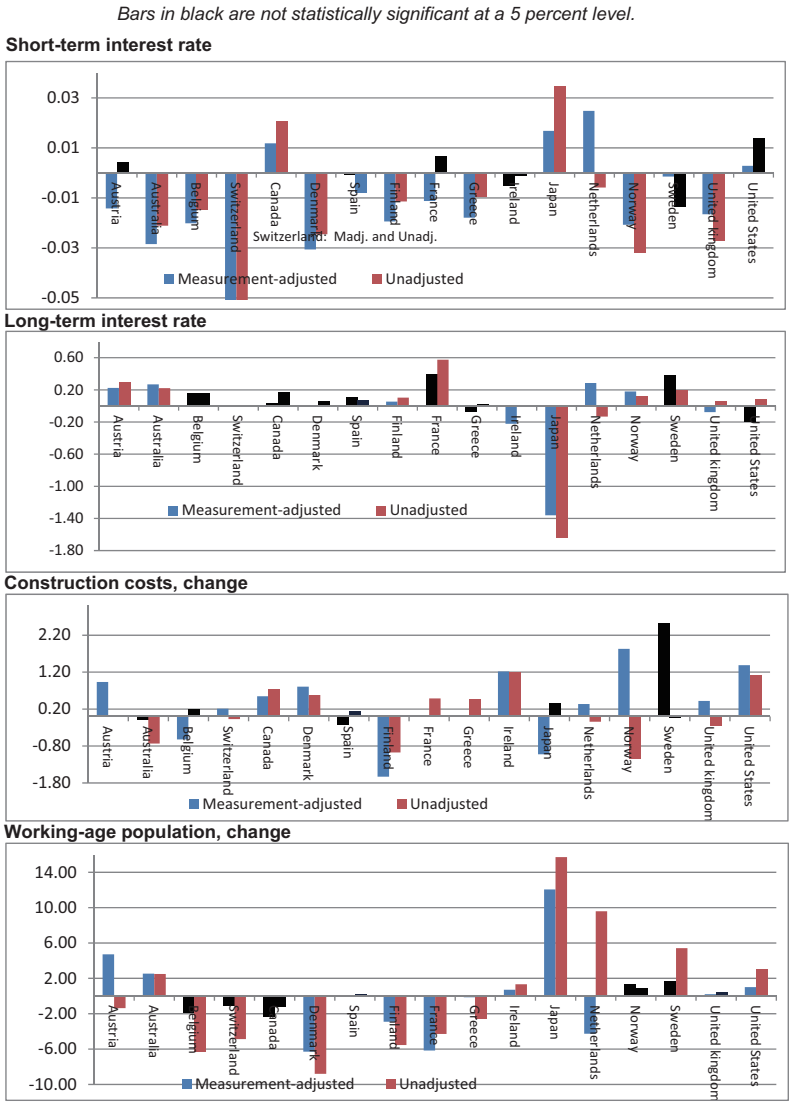


Fig. 7b, continued. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/JEM-150406)

larger falls when measurement-adjusted HPIs are used, while in others the impact of measurement-adjustment is mixed. The disparity between the estimated parameters arising from using measurement-adjusted and unadjusted HPIs, as well as the magnitude of their effects, can be quite marked in some countries, including Japan, Netherlands, Switzerland, the United Kingdom and the United States.

5. Conclusions

The paper is motivated by the wide variation in the form HPIs can take both with respect to coverage and method [9]. As noted in Section II, HPIs have been identified as a key data gap by G-20 with current initiatives to ameliorate such differences being undertaken by the Bank of International Settlements, Financial Stability Board, IMF, Eurostat, the European Central Bank, and the (United Nations) Inter-Secretariat Working Group on Price Statistics. Using three country case studies, Silver [32] identified substantial differences in measured national house price inflation between different indexes *within* a country.

This paper provides an extensive and formal analysis of this measurement problem involving panel data from 24 countries and 153 HPIs over the period 2005Q1 to 2010Q1. The results clearly demonstrate that measurement matters; substantively so and particularly when it really matters, during a recession. Different patterns over time were distinguished for the effects (coefficients) on house price inflation of different measurement variables.

Given measurement matters, we turned in Section IV to determine how measurement might matter for economic analysis. We adopted a model of house price changes by Igan and Loungani [17] and used, in turn, our measurement-adjusted and unadjusted HPIs. Measurement-adjusted HPIs were found to perform better in the model with parameters constrained to be the same for all countries. In particular, stock price changes and long-term interest rates entered the measurement-adjusted model as statistically significant, unlike the unadjusted model. However, stock price changes entered both of these pooled regressions as statistically significant when the coefficients were allowed to vary between countries, though the magnitudes were quite different. The coefficients on stock price changes followed the pattern identified for (lagged) affordability, credit, and income per capita: coefficients of explanatory variables relating to measurement-adjusted HPI change have larger falls and smaller increases than their unadjusted counterparts.

In sum, measurement matters, particularly and substantially so during the recession. However, economic models, if specified in a sufficiently flexible way, are robust to such measurement problems except for a differential magnitude in the measured effect, something relevant to macroeconomic policy formulation.

Appendix 1: Source data on house price indexes for Silver

Many of the house price indexes (HPIs) used in this study have been drawn from the Bank for International Settlements' (BIS) database of property price indexes available at: http://www.bis.org/statistics/pp.htm. The codes cited below alongside "BIS" refer to this database. Use of the database requires a citation of the appropriate national source as noted at: http://www.bis.org/statistics/pp/disclaimer.htm. These are given below. The BIS country series have been supplemented by further HPIs, not always published, as indicated.

Australia: 14 series

BIS: Q:AU:2:1:1:1:0:0 and Q:AU:4:1:1:1:0:0; House Price Indexes; original source: Australian Bureau of Statistics: http://www.abs.gov.au/AUSSTATS/abs@.nsf/DetailsPage/6464.02009?OpenDocument.

RP Data; RP Data-Rismark's Home Value Indexes: Capital Gain (final values), Repeat Sales, and Stratified median; data provided to author by RP Data; website: http://www.rpdata.com/. See also: www.rpnz.com.au/derivatives/pdfs/Basing_NZ.pdf.

Austria: 10 series

BIS:Q:AT:2:8:0:0:1:0, Q:AT:1:1:0:0:1:0, Q:AT:1:8:0:0:1:0, Q:AT:2:8:1:0:1:0, Q:AT:1:2:1:0:1:0, Q:AT:1:8:1:0:1:0, Q:AT:1:8:2:0:1:0, Q:AT:2:1:0:0:1:0, Q:AT:2:2:1:0:1:0, Q:AT:2:8:1:0:1:0; House Price Index; original source: Oesterreichischen Nationalbank: http://www.oenb.at/isaweb/report.do?lang=EN&report=6.6.

Belgium: 8 series

BIS: Q:BE:2:2:1:2:0:0; Stadim Indexes; original source and further indexes: STADIM (Study and Advice Bureau on Immovables): http://www.stadim.be/index.php?page=stadimdexen&hl=en.

BIS: Q:BE:0:1:1:0:0:0, Q:BE:0:2:1:0:0:0, Q:BE:0:3:1:0:0:0, Q:BE:0:4:1:0:0:0, and Q:BE:0:8:1:0:0:0; Prix Ventes de Biens Immobiliersoriginal; original source: SPF Economie, DGSIE (Service public federal Economie, Direction Generale Statistique et Information Economique (FPS Economy, DGSEI (Federal Public Service, Directorate-General Statistics and Economic Information)): http://statbel.fgov.be/fr/modules/publications/statistiques/economie/ventes_de_biens_immobiliers.jsp.

Canada: 6 series

Teranet (developed in alliance with the National Bank of Canada); Teranet House Price Index; source: http://www.housepriceindex.ca/Default.aspx.

New Housing Price Index; Statistics Canada; source: http://www.statcan.gc.ca/daily-quotidien/110210/dq110210a-eng.htm.

Resale-Housing Prices (Royal LePage); Bank of Canada; source: http://www.bankofcanada.ca/en/rates/indinf/real_data_en.html.

The Canadian Real Estate Association (CREA); Residential Average Price; source: CREA, available on subscription: http://creastats.crea.ca/natl/.

Czech Republic: 2 series

BIS: Q:CZ:0:2:1:1:3:0 and Q:CZ:0:8:1:1:1:0; Price Indexes of Houses and Flats; original source: Czech Statistical Office, Tables 1–6 and 2–6: http://www.czso.cz/CSU/2009EDICNIPLAN.NSF/P/7009-09.

Denmark: 4 series

BIS: Q:DK:0:2:0:1:0:0 and Q:DK:0:8:0:1:0:0; Price index for sales of property; original source: Statistics Denmark: http://www.statbank.dk/STATBANK5A/DEFAULT.ASP?W=1024.

Association of Danish Mortgage Banks; Average Sqm. Prices of Owner Occupied Dwellings: http://www.realkreditraadet.dk/Statistics/Prices_and_trades_of_owner_occupied_homes.aspx.

Estonia: 2 series

BIS: Q:EE:0:8:0:1:1:0 and Q:EE:2:8:0:1:1:0; original source via Statistics Estonia: Estonian Land Board from whose website a data query facility is available: http://www.maaamet.ee/kinnisvara/htraru/Start.aspx. The facility is in Estonian, however, an English-language Guide to its use and technical information are available at: http://www.maaamet.ee/index.php?lang_id=2&page_id=453&menu_id=78.

Finland: 9 series

BIS: Q:FI:0:1:1:1:1:0, Q:FI:0:1:2:1:1:0, Q:FI:0:2:1:1:1:0, Q:FI:0:8:1:1:1:0, Q:FI:4:2:1:1:1:0, Q:FI:9:1:1:1:1:0, Q:FI:9:1:2:1:1:0, Q:FI:A:1:1:1:1:0, and Q:FI:A:1:2:1:1:0; House Price Index; original source: Statistics Finland, unpublished and available from Bank of Finland (Suomen Pankki): http://www.suomenpankki.fi/en/julkaisut/selvitykset_ja_raportit/main/Pages/default.aspx.

France: 8 series

BIS: Q:FR:2:8:1:1:0:0; Indice d'Évolution des Prix des Logements Anciens: original source: INSEE, National Institute of Statistics and Economic Research: http://www.insee.fr/fr/themes/document.asp?ref_id=ip1297 and http://www.indexes.insee.fr/bsweb/servlet/bsweb?action=BS_RECHGUIDEE&BS_IDARBO=05000000000000.

BIS: Q:FR:0:2:2:3:0:0, Q:FR:0:8:2:3:1:0, Q:FR:3:2:2:3:0:0, and Q:FR:3:8:2:3:1:0; Enquete Commercialsation Logements Nuefs; original source: Ministère de l'Equipment Ministère de l'Écologie, de l'Énergiie, du Développement durable, et de la Mer (Meeddm).

Greece: 9 series

BIS: Q:GR:0:8:0:0:0:0, Q:GR:0:8:1:0:0:0, Q:GR:0:8:2:0:0:0, Q:GR:1:1:0:0:1:0, Q:GR:3:8:0:0:1:0, Q:GR:4:8:0:0:1:0, Q:GR:5:8:0:0:0:0, Q:GR:8:8:0:0:0:0, and Q:GR:9:8:0:0:1:0; Index of the Price of Dwellings; original source: Bank of Greece: http://www.bankofgreece.gr/PAGES/EN/STATISTICS/REALESTATE.ASPX.

Ireland: 11 series

BIS: Q:IE:0:1:0:2:0:0, Q:IE:1:1:0:2:0:0, and Q:IE:2:1:0:2:0:0; Permanent tsb House Price Index; original source: Economic and Social Research Institute (ESRI) based on data from Permanent TSB Bank; http://www.esri.ie/irish_economy/permanent_tsbesri_house_p/ and https://www.permanenttsb.ie/aboutus/housepriceindex/#d.en.1460.

BIS: Q:IE:0:1:1:3:0:0, Q:IE:0:1:2:3:0:0, and Q:IE:2:1:1:3:0; Average house prices; original source and further series: The Department of the Environment, Heritage, and Local Government; available at: http://www.environ.ie/en/Publications/StatisticsandRegularPublications/HousingStatistics/FileDownLoad,15295,en.XLS and http://www.environ.ie/en/Publications/StatisticsandRegularPublications/HousingStatistics/.

Netherlands: 10 series

BIS: M:NL:0:1:1:1:0:0, M:NL:0:2:1:1:0:0, and M:NL:0:8:1:1:0:0; House Price Index and Average Purchase Prices; original source and further series: CBS (Central Bureau voor de Statistiek) published in cooperation with the Dutch Land registry Office, Kadaster: http://statline.cbs.nl/STATWEB/SELECTION/?DM=SLEN&PA=71533ENG&LA=EN&VW=T.

New Zealand: 3 series

BIS: Q:NZ:0:1:0:3:0:0, Q:NZ:0:3:0:3:0:0, and Q:NZ:4:3:0:3:0:0; Quotable Value Quarterly House Price Index; original source: Quotable Value Limited; available at: Reserve Bank of New Zealand: http://www.rbnz.govt.nz/keygraphs/1697975.html.

Norway: 4 series

BIS: Q:NO:0:1:0:1:0:0, Q:NO:0:3:0:1:0:0, Q:NO:0:4:0:1:0:0, and Q:NO:0:8:0:1:0:0; House Price Index; original source and further series (see "More Tables in StatBank"): Statistics Norway: http://www.ssb.no/english/subjects/08/02/30/bpi_en/.

Poland: 4 series

BIS: Q:PL:2:8:1:2:1:0, Q:PL:2:8:2:2:1:0, Q:PL:4:8:1:2:1:0, and Q:PL:4:8:2:2:1:0; Average Asking Prices of Flats; original source: National Bank of Poland (growth rates): http://www.nbp.pl/HOMEN.ASPX?F=/EN/SYSTEMFINANSOWY/STABILNOSC.HTML.

Russia: 2 series

BIS: Q:RU:9:1:1:1:1:0 and Q:RU:9:1:2:1:1:0; Indexes of Prices in Primary/Secondary Market of Dwellings; original source: Federal State Statistics Service: http://www.gks.ru/wps/wcm/connect/rosstat/rosstatsite.eng/figures/prices/.

Slovak Republic: 3series

BIS: Q:SK:0:1:1:2:1:0; House Price Indexes; original source and further series: National Bank of Slovakia: http://www.nbs.sk/EN/STATISTICS/SELECTED-MACROECONOMICS-INDICATORS/RESIDENTIAL-PROPERTY-PRICES.

Slovenia: 6 series

BIS: Q:SI:0:1:1:1:0:0, Q:SI:0:8:2:1:0:0, and Q:SI:2:1:1:1:0:0; Residential Housing Price Indexes; original source and further series: Statistical Office of the Republic of Slovenia: http://www.stat.si/eng/novica_prikazi.aspx?id=3714.

Spain: 2 series

BIS: Q:ES:0:1:1:1:1:0 and Q:ES:0:1:2:1:1:0; Precio M^2 Vivienda Libre; original source: Banco de Espana: http://www.bde.es/infoest/si_1_6.csv.

Sweden: 2 series

BIS: Q:SE:0:1:0:1:0:0; Real Estate Prices; original source and other indexes; Statistics Sweden: http://www.scb.se/Pages/Product_10966.aspx and http://www.ssd.scb.se/databaser/makro/produkt.asp?produktid=BO0501&lang=2.

Switzerland: 6 series

BIS: CH:0:2:0:2:0:0 and CH:0:8:0:2:0:0; Real Estate Price Indexes; original source: Swiss National Bank: http://www.snb.ch/en/iabout/stat/statpub/statmon/stats/statmon/statmon_O4_3 (original source: Wüest & Partner AG).

Wüest & Partner AG; Transaction and Asking Price Indexes: http://www.wuestundpartner.com/online_services/immobilienindizes/transaktionspreisindex/index_e.phtml.

United Kingdom: 27 series

BIS: Q:GB:3:1:0:2:0:0; Halifax House Price Index; original source and further series: Halifax Research: http://www.lloydsbankinggroup.com/media1/research/halifax_hpi.asp (historical house price data).

BIS: Q:GB:0:1:2:1:0:0; Communities and Local Government House Price Index; original source and further series: Department of Communities and Local Government, available at: http://www.communities.gov.uk/housing/housingresearch/housingstatistics/housingstatisticsby/housingmarket/housepriceindex/. Also available from UK (Office for) National Statistics at: http://www.statistics.gov.uk/hub/people-

places/housing-and-households/housing-market/index.html. (© Crown copyright 2008 Land Registry).

Acadametrics; LSL Property Services/Acadametrics House Price Index; source: http://www.acadametrics.co.uk/acadHousePrices.php. Land Registry; House Price Index; source: http://www.landreg.gov.uk/houseprices/.

Nationwide; Nationwide House Price Index; source: http://www.nationwide.co.uk /hpi/historical.htm.

Rightmove; House Price Index; source: http://www.rightmove.co.uk/news/house-price-index.

United States: 4 series

BIS: Q:US:0:2:2:1:0:0; US Census Bureau; Constant Quality (Laspeyres) Price Index of New One-Family Houses Sold; original source: http://www.census.gov/ const/www/constpriceindex.html.

Federal Housing Finance Agency (FHFA); FHFA "Purchases-Only" House price index; source: http://www.fhfa.gov/DEFAULT.ASPX?PAGE=84.

Standard & Poor's; S&P/Case-Shiller National Home Price Index; source: http: //www.standardandpoors.com/indexes/sp-case-shiller-home-price-indexes/en/us/? indexId=spusa-cashpidff–p-us—-.

CoreLogic Home Price Index, source: http://www.corelogic.com/about-us/resear chtrends/home-price-index.aspx.

Appendix 2: Regression with constrained fixed (over time) parameters

A regression was estimated with fixed (over time) parameters on the coverage and measurement variables, the results of which are given in the Table below. A parsimonious set of these variables was selected from a general model. Of note is the low $\bar{R}^2$ of 0.0503 when measurement variables and fixed country effects are included. This substantively holds even for the general model. Only three measurement variables are statistically significant at a 5 percent level. Yet when the explanatory measurement variables were tested as being redundant against a specification that included measurement variables *and* fixed-country effects, the null hypothesis of redundant variables could not be rejected at a 1 percent level (LLR $= 16.81$, p-value $= 0.665$). Measurement, at least in this representation, did *not* seem to matter.

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Appendix 2 Table 1
Regression of RPPIs on measurement variables

Variable	Coefficient	Std. Error	t-Statistic
APARTMENT	−0.0002	0.0017	−0.114
APPRAISAL	0.0039	0.0052	0.744
ASKING	0.0014	0.0035	0.412
CAPITAL	0.0009	0.0014	0.642
HEDONIC	−0.0039	0.0035	−1.113
MIXADJUST	0.0015	0.0020	0.737
NEW	0.0001	0.0029	0.037
SFH	0.0008	0.0023	0.345
SQMETER	0.0054	0.0043	1.263
UNWEIGHTED	−0.0082	0.0027	−3.039
WPRICE	0.0123	0.0049	2.486
WROLLING	−0.0078	0.0025	−3.092
WSTOCK	−0.0021	0.0022	−0.985
XSTING	−0.0006	0.0023	−0.236
R-squared	0.0611	Adjusted R-squared	0.0503
S.E. of regression	0.0405	Log likelihood	5663.6

Sample: 2005Q1 to 2010Q1; 155 cross-sections; 3,156 obs. Fixed country effects not shown for brevity.

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